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Docket No.: END9 1999 0129 US1

**NEW UTILITY PATENT APPLICATION TRANSMITTAL****(Large Entity)***(Only for new nonprovisional applications under 37 CFR 1.53(b))*

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**TO THE ASSISTANT COMMISSIONER FOR PATENTS**Box Patent Application  
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:  
SYSTEM AND METHOD FOR NETWORK ADDRESS TRANSLATION INTEGRATION WITH IP SECURITY

and invented by:

EDWARD B. BODEN, MARK J. MELVILLE, TOD A. MONROE, FRANK V. PAXHIA

**If a CONTINUATION APPLICATION**, check the appropriate box and supply the requisite information:

☐ Continuation   ☐ Divisional   ☒ Continuation-in-part(CIP) of prior application  
No.: 09/240,720 FILED 29 JAN 1999.

Enclosed are:

**Application Elements**

01. ☒ Filing fee as calculated and transmitted as described below
02. ☒ Specification having 50 pages and including the following:
  - a. ☒ Descriptive Title of the Invention
  - b. ☒ Cross References to Related Applications *(if applicable)*
  - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
  - d. ☐ Reference to Microfiche Appendix *(if applicable)*
  - e. ☒ Background of the Invention
  - f. ☒ Brief Summary of the Invention
  - g. ☒ Brief Description of the Drawings *(if drawings filed)*
  - h. ☒ Detailed Description
  - i. ☒ Claim(s) as Classified Below
  - j. ☒ Abstract of the Disclosure
03. ☒ Drawing(s) when necessary as prescribed by 35 USC 113)
  - a. ☐ Formal
  - b. ☐ Informal

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16. ☐ Additional Enclosures (identify below)

**CLAIMS AS FILED**

☐ A check in the amount of \$ \_\_\_\_\_ to cover the filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and credit IBM Corporation Deposit Account No. 09-0457 as described below. A duplicate copy of this sheet is enclosed.

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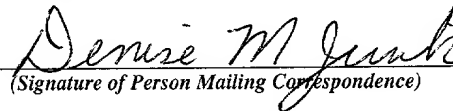
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Invention: **System And Method For Network Address Translation Integration With IP Security**15789 U.S. PRO  
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08/23/00I hereby certify that this **New Patent Application, IDS w/References, Assignment w/Cover Sheet**  
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**APPLICATION**

**FOR**

**UNITED STATES LETTERS PATENT**

APPLICANT NAME E. B. BODEN, ET AL

TITLE SYSTEM AND METHOD FOR  
NETWORK ADDRESS TRANSLATION  
INTEGRATION WITH IP SECURITY

DOCKET NO. END9 1999 0129 US1

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## Cross References to Related Applications

U.S. patent applications Serial No. 09/239,693, filed  
1/29/99, entitled System and Method for Managing Security  
Objects; Serial No. 09/240,718, filed 1/29/99, entitled  
"System and Method for Dynamic Macro Placement of IP  
Connection Filters"; S/N 09/239,694, filed 1/29/99, entitled  
"System and Method for Dynamic Micro Placement of IP  
Connection Filters"; S/N 09/240,483, filed 1/29/99, entitled  
"System and Method for Central Management of Connections in  
a Virtual Private Network, are assigned to the same assignee  
hereof and contain subject matter related, in certain  
respects, to the subject matter of the present application.  
The above-identified patent applications are incorporated  
herein by reference.



this greatly increases the likelihood of IP address  
conflicts.

Network Address Translation (NAT) is widely deployed in  
Internet and in companies connecting to the Internet to  
5 overcome address conflicts. These conflicts commonly occur  
between designated 'private' address spaces (e.g. 10.\*.\*.\*).

However, NAT and IP Security (IP Sec) are  
architecturally conflicting. In fact, NAT breaks IP Sec.  
That is, NAT "is the feature which finally breaks the  
10 semantic overload of the IP address as both a locator and  
the end-point identifier" (see, "Architectural Implications  
of NAT", draft-iab-nat-implications-00.txt, March 1998.  
IPSec is described in Kent, S., and Atkinson, "Security  
Architecture for the Internet Protocol", RFC2401, November  
15 1998; Kent, S., and Atkinson, "IP Authentication Protocol",  
RFC 2402, November 1998; and Kent, S., and Atkinson, "IP  
Encapsulation Security Payload", RFC 2406, November 1998.)  
As a result, two hosts cannot establish an IP Sec connection  
if there is a NAT system in between. There are two reasons  
20 why. First, the IP traffic that flows between the two hosts



(for the IP Sec connection) will have authentication protocol (AH) or encapsulation security payload (ESP) applied. (See RFC's 2402 and 2406, supra.)

5 First, with respect to ESP in tunnel mode, the IP address that needs to be translated is inside the ESP tunnel and is encrypted. It is, therefore, unavailable to NAT. With respect to AH in transport or tunnel mode, the IP address that needs to be translated is visible in NAT, but the AH authentication includes it. Therefore, changing the  
10 IP address will break the authentication at the remote end of the IP Sec connection. With respect to ESP in transport mode, even if ESP is used with authentication, the IP address is available to NAT. But, if the IP address is changed, the IP Sec connection breaks due to the breaking of  
15 authentication at the remote end of the IP Sec connection.

Second, even if the IP traffic for the IP Sec connection could be translated, it would fail because the IP Sec connection is based on Security Associations which contain the two host IP addresses. These are fundamental to  
20 the Security Association architecture (see RFC 2401, supra),

in that the inbound IP Sec, on the host where decrypting (or authentication) is to occur, must be uniquely determined by the triple:

{destination IP addr, SPI, IP Sec protocol}.

5 where SPI is the security protocol index (see, RFC 2401, supra).

For example, given hosts A & W, assume NAT is applied to an IP datagram (a generic term for bytes that go on the wire) with ESP in transport mode that is going from A to W. Hence the IP source address is changed. Upon arrival at W, the packet will probably be decrypted successfully since that doesn't depend on IP source address (which was in plaintext -- not tunneled). If strictly implemented however, the inbound SPD checking which should follow decrypting will fail, due to the changed IP source address (because it was not the address used to negotiate the security association). So, even the transport mode ESP case fails.

Simply making NAT and IP Sec mutually exclusive is not the solution sought by the art. NAT is being deployed widely because it solves many problems, such as: masks global address changes, lowers address utilization, lowers Internet service provider (ISP) support burden, and allows load sharing as virtual hosts.

Yet, NAT is viewed as the greatest single threat to security integration being deployed in the Internet today. This "NAT problem", as it is invariably termed, is architecturally fundamental. Yet, legacy applications and services (for example, those developed for IP version 4) will continue to a long co-existence as applications and services develop for IP version 6. Consequently, there is a great need in the art for providing NAT and IP Sec coexistence, at least in selected situations, and to do so without introducing serious configuration problems. (IP version 4 is described in "Internet Protocol", RFC791, September 1981. IP version 6 is described in Deering, S., Hinden, R., "Internet Protocol, Version 6 (IPv6) Specification", RFC2460, December 1998.)

A VPN connection between two address domains can have the effect of directly connecting two domains which most likely will not been planned to be connected. Hence increased use of VPNs is likely to increase address conflicts. It is also understood that VPNs redefine network visibility and increase the likelihood of address collision when traversing NATs. Address management in the hidden space behind NATs will become a significant burden. There is, therefore, a need in the art to ameliorate that burden.

In U.S. Patent Application Serial No. 09/240,720, a solution to the general problem of integrating IP Sec and NAT is presented. IP security is provided in a virtual private network using network address translation (NAT) by performing one or a combination of the four types of VPN NAT. (Three types of VPN NAT will be further described hereafter, and the fourth is described in copending patent application, assignee docket END9 1999 0093, supra.) This involves dynamically generating NAT rules and associating them with the manual or dynamically generated Internet key exchange (IKE) Security Associations, before beginning IP security that uses the Security Associations. (See, Harkins, D., Carrel, D., "The Internet Key Exchange (IKE)", RFC2409, November 1998. Security Associations is a term

defined in RFC201, supra.) Then, as IP Sec is performed on  
outbound and inbound datagrams, the NAT function is also  
performed. By "perform IP Sec", is meant to execute the  
steps that comprise IP Sec outbound or inbound processing,  
5 as defined by the 3 IP Sec RFCs (and others) above. By  
"perform NAT", is meant to execute the steps that comprise  
the VPN NAT processing hereafter described in this  
application.

10 In U.S. Patent Application Serial No. 09/240,720, the  
customer must configure each separate VPN NAT rule as a  
separate VPN connection. This is time consuming and prone  
to error, and VPN connections are really meant to protect  
the traffic and should be independent of specific VPN NAT  
rules. That is, the rules have heretofore been one to one -  
15 NAT thus increases the number of VPN connections required.

It is an object of the invention to provide an improved  
and greatly simplified system and method for concurrently  
implementing both Network Address Translation (NAT) and IP  
Security (IP Sec).

It is a further object of the invention to provide a system and method for solving the increased likelihood of IP address conflicts inherent in the use of a virtual private network (VPN).

5           It is a further object of the invention to provide a system and method for enabling utilization of VPNs without requiring re-addressing a domain (an expensive alternative).

10           It is a further object of the invention to provide a system and method for VPN NAT which is accomplished entirely in the IP Sec gateway without requiring changes in domain hosts.

          It is a further object of the invention to provide a system and method for VPN NAT which requires no, or only minor, changes to routing in each connected domain.

15           It is a further object of the invention to provide a system and method for VPN NAT which is simple to configure.

          It is a further object of the invention to provide a solution to the address collision problems caused by VPNs.



Variable	Mean	SD	Min	Max
Age	34.5	10.5	18	65
Gender	50%	50%	Male	Female
Marital status	75%	25%	Married	Single
Education	12.5	2.5	9	16
Income	1500	500	500	3000
Occupation	30%	70%	Manager	Worker
Health status	80%	20%	Good	Poor
Smoking status	40%	60%	Smoker	Non-smoker
Alcohol consumption	30%	70%	Drinker	Non-drinker
Exercise frequency	20%	80%	Regular	Irregular
Stress level	60%	40%	Low	High
Sleep quality	70%	30%	Good	Poor
Dietary habits	50%	50%	Healthy	Unhealthy
Family size	3.5	1.5	1	6
Religious beliefs	60%	40%	Religious	Secular
Political views	50%	50%	Conservative	Liberal
Travel frequency	20%	80%	Frequent	Rarely
Pet ownership	30%	70%	Owner	Non-owner
Gardening interest	40%	60%	Interested	Not interested
Volunteering	10%	90%	Volunteer	Non-volunteer
Charitable donations	20%	80%	Donor	Non-donor
Community involvement	30%	70%	Active	Passive
Neighborhood satisfaction	60%	40%	Satisfied	Dissatisfied
Local government trust	50%	50%	Trust	No trust
Local business support	40%	60%	Support	No support
Local infrastructure quality	70%	30%	Good	Poor
Local safety perception	80%	20%	Safe	Unsafe
Local environmental quality	60%	40%	Good	Poor
Local cultural activities	50%	50%	Active	Passive
Local social cohesion	70%	30%	High	Low
Local economic growth	60%	40%	High	Low
Local employment opportunities	50%	50%	Good	Poor
Local housing affordability	40%	60%	Good	Poor
Local transportation accessibility	60%	40%	Good	Poor
Local public services quality	70%	30%	Good	Poor
Local healthcare access	80%	20%	Good	Poor
Local education quality	70%	30%	Good	Poor
Local cultural heritage preservation	60%	40%	Good	Poor
Local historical landmarks	50%	50%	Good	Poor
Local natural beauty	70%	30%	Good	Poor
Local recreational facilities	60%	40%	Good	Poor
Local green spaces	50%	50%	Good	Poor
Local air quality	60%	40%	Good	Poor
Local water quality	70%	30%	Good	Poor
Local waste management	60%	40%	Good	Poor
Local noise levels	50%	50%	Low	High
Local security measures	60%	40%	Good	Poor
Local emergency services	70%	30%	Good	Poor
Local disaster preparedness	60%	40%	Good	Poor
Local climate resilience	50%	50%	Good	Poor
Local sustainability efforts	60%	40%	Good	Poor
Local renewable energy use	50%	50%	Good	Poor
Local green building standards	60%	40%	Good	Poor
Local smart infrastructure	50%	50%	Good	Poor
Local digital connectivity	70%	30%	Good	Poor
Local broadband access	80%	20%	Good	Poor
Local mobile phone usage	90%	10%	Good	Poor
Local internet usage	80%	20%	Good	Poor
Local social media usage	70%	30%	Good	Poor
Local online shopping	60%	40%	Good	Poor
Local digital literacy	50%	50%	Good	Poor
Local digital privacy	60%	40%	Good	Poor
Local digital security	70%	30%	Good	Poor
Local digital inclusion	60%	40%	Good	Poor
Local digital innovation	50%	50%	Good	Poor
Local digital entrepreneurship	60%	40%	Good	Poor
Local digital marketing	70%	30%	Good	Poor
Local digital advertising	80%	20%	Good	Poor
Local digital analytics	60%	40%	Good	Poor
Local digital customer service	70%	30%	Good	Poor
Local digital product development	60%	40%	Good	Poor
Local digital supply chain management	50%	50%	Good	Poor
Local digital logistics	60%	40%	Good	Poor
Local digital inventory management	70%	30%	Good	Poor
Local digital procurement	60%	40%	Good	Poor
Local digital sales	70%	30%	Good	Poor
Local digital distribution	80%	20%	Good	Poor
Local digital fulfillment	70%	30%	Good	Poor
Local digital returns management	60%	40%	Good	Poor
Local digital customer feedback	70%	30%	Good	Poor
Local digital brand management	60%	40%	Good	Poor
Local digital reputation management	70%	30%	Good	Poor
Local digital crisis management	60%	40%	Good	Poor
Local digital legal compliance	50%	50%	Good	Poor
Local digital tax compliance	60%	40%	Good	Poor
Local digital accounting	70%	30%	Good	Poor
Local digital human resources	60%	40%	Good	

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## Brief Description of the Drawings

Figure 1 is a flow diagram of the VPN NAT method of the preferred embodiment of the invention.

5 Figure 2 illustrates typical IP Sec scenarios and associated VPN NAT pools.

Figure 3 illustrates static NAT, the simplest conventional NAT, for context.

Figure 4 illustrates masquerade NAT, a type of conventional NAT, for context.

10 Figure 5 illustrates VPN NAT, type a (aka 'source-out'): IDci translated for initiator-mode conversations.

Figure 6 illustrates VPN NAT, type c (aka 'source-in'): IDci translated for responder-mode conversations.

15 Figure 7 illustrates VPN NAT, type d (aka 'destination-in'): IDcr translated for responder-mode conversations.



header, address translation is not done. This applies to inbound and outbound NAT. So, the effect is that for conventional NAT (versus VPN NAT for IP Sec, or IP Sec NAT), preference is given to IP Sec. IP Sec overrides conventional NAT.

Since it is not known at the time the NAT rules are loaded whether or not any IP Sec connections might conflict (dynamic IP for example), checking for such problems cannot be done until actual NAT processing in the operating system kernel. User visibility to these actions is provided, if journaling is on for the rule, by indicating in a journal entry that a NAT rule fits the datagram, but was not done due to IP Sec. In addition, operating system kernel information logging of these actions may be provided for some limited number of occurrences per conventional NAT rule. Similarly, a message per connection, rather than per occurrence, may be provided in a connection manager job log or in a connection journal. "Journaling" and "journal entry" are terms also referring to what is typically known in the art as "logging" and "log entry", respectively.

Pursuant to the invention described in the parent application, referred to as VPN NAT, to allow NAT to be used with IP Sec at the IP Sec gateway, customers retain private internal IP addresses, and increased address collision is avoided by having IP Sec connections begin and end at the IP Sec gateway. An IP Sec gateway is a term defined in RFC2401, supra. The term "VPN connection" is another term referring to what is generally called an "IP Sec tunnel", the latter being defined in RFC2401, supra.

Further in accordance with the parent application, virtual private networks (VPN) are provided in both initiator and responder modes with an integrated NAT function. Security associations are negotiated using the proper external (NAT rhs) IP addresses, and the NATing of corresponding internal (NAT lhs) IP addresses is done by generated NAT rules, in sync with connection load to IPsec and IPsec processing in Operating system kernel. Inbound source IP addresses are translated, as well as the usual source IP address NAT on outbound (with corresponding translation of destination IP address on inbound). A 'VPN NAT rule' is represented by blocks 126, 124 in Figure 5; that is, the 2 sets of lhs and rhs addresses comprise a VPN NAT rule.



In step 20, the user decides on and configures the connections that will require NAT. This is logically equivalent to writing NAT rules. The four cases to be considered in doing so are depicted in Table 1.

5

TABLE 1: TYPES OF VPN NAT			
		IDci (source)	IDcr (destination)
10	Initiator Mode	source-out type a.NAT internal address, IP src on outbound, IP dest on inbound.	destination-out type b.NAT
15	Responder Mode	source-in type c.NAT external address, IP src on inbound, IP dest on outbound.	destination-in type d.NAT internal address, IP dest on inbound, IP src on outbound.

20

where IDci = 'identifier of client initiator',  
IDcr = 'identifier of client responder'.

A VPN connection is defined as having four endpoints:  
two 'connection endpoints', and two 'data endpoints'.

25

(Transport mode then means that the connection endpoint equals the data endpoint, at each end of the connection.)  
The IDci and IDcr terms refer to the two data endpoints, more specifically, by indicating which is the initiator and which is the responder (see, RFC2409, supra.) Also, these

identifiers may take one of about six different forms, which are part of the IDcr, IDcr definitions. For this application, identifier types are not particularly relevant.

When specifying a specific instance of NAT in, for example, an IP Sec Policy database, the user makes a yes/no decision in, say, a check-box. As used herein, an IP Sec policy refers to the complete set of configured IP Sec information, on a system. This information is stored in what is termed the IP Sec database, or IP Sec policy database. Responder mode NAT flags IDci and IDcr may be part of the connection definition. The initiator mode flag may be part of the user client pair, associated with a 'local client ID' (only). The responder IDci and IDcr NAT flags can be set independently. Both are relevant only if the connection definition has external initialization mode.

Heretofore, in all cases, if the NAT flag was 'on', the corresponding granularity value was required to be 's' (scalar) in the connection definition. In accordance with the present invention, this is no longer a restriction with dynamic VPN NAT. That is, granularity of 's' (scalar), 'f' (filter) and 'c' (client) are all supported. 'Granularity' is described in RFC2401, supra, at pages 15-16. In

accordance with an exemplary embodiment of the invention,  
for example the IBM AS/400, 'granularity' is implemented as  
follows: each VPN connection has five selectors (fields in  
5 datagram that might be checked to determine if traffic  
should be in the VPN connection; these are: source IP, dest  
IP, source port, destination port and protocol. In  
accordance with this exemplary embodiment, when a VPN  
connection is started, each selector get its value from  
either (1) the policy filter for that VPN connection (for  
10 selector granularity 'f'), (2) single values from IKE (for  
selector granularity 's'), or (3) contiguous range of values  
from IKE (for selector granularity 'c').

Referring to Figure 2, the manner in which VPN NAT IP  
pools relate to network scenarios is shown. Lines 34 and 36  
15 represent IP Sec connections between gateways (GW) 42, 44  
and 46 on Internet 40. NAT pools 52, 54 for types 'a  
source-out' and 'c source-in' are independently associated  
with each remote ID (gateway 44, 46). For type 'd  
destination-in' VPN NAT, a single pool 50 may be defined for  
20 global IP addresses that the VPN NAT gateway 42 owns. In  
this exemplary embodiment, IP SEC policies for NAT pools 50,  
52, 54 are stored in IP SEC data base 48. In this example,  
all three internal networks 56, 58 and 60 use the same



10.\*.\*.\* addresses space. This provides the initial value and motivation for VPN NAT: IP Sec tunnels (aka connections) between these internal networks 56, 58, 60 has a logical effect combining them. This cannot be done, in general, without address conflict. VPN NAT provides the solution to the problem presented to gateway (Gw 1) 42 when it needs to do business with hosts behind gateways (Gw Q) 44 and (Gw Y) 46 on internal networks 60 and 58, respectively.

In step 22, the user defines a set (in pools 50, 52 and 54) of IP addresses that are available for the exclusive use of the VPN NAT function. Each pool is preferably definable as a range of IP address, but could be a list of discontinuous addresses, and is naturally associated with remote ID and local ID IP Sec Policy database entities.

Referring to Table 2, the different meanings of each flavor of VPN NAT motivating the different pools are set forth. Although specified on a per remote ID or local ID basis, the pools may be managed as three distinct groups of IP addresses. This allows the user to specify, for example, the same range for multiple remote ID's. The letters a, c



5

Hence, a pool  
may be  
associated with  
a globally  
routable IP  
address (IDcr).

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In step 24, initiator mode connections are started.  
When starting an initiator mode connection, the connection  
10 manager checks if the local client ID is to be translated.  
If so, the connection manager looks for an available IP  
address from NAT pool, say 52, associated with a remote ID  
in the database. Availability is determined by the  
connection manager as follows. The connection manager is a  
15 server which, running all of the time, starts and stops VPN  
connections and provides status. This server maintains a  
single (system-wide, since connection manager runs once per  
system) list of IP addresses that have been used in some  
active connection (states: starting, running or stopped)  
20 from any type 'a source-out' pool (see Table 1). The first  
IP address in the pool not in the used list, is chosen, and  
added to the used list. If an available IP address cannot  
be found, the connection is not started and an appropriate  
error message (and possibly return code to the OP NAV GUI)  
25 is generated. The policy database is not updated to show an  
IP address is in use -- rather this is determined  
dynamically by the connection manager based solely on its

set of active connections. An 'OP NAV GUI' is an "AS/400 Operations Navigator graphical user interface (GUI)", a PC-based GUI used to configure various aspects of AS/400, including VPN.

5           The start message (msg) sent by connection manager to IKE will have the NAT rhs IP address selected from the pool. The NAT rhs IP address is added to the security association (SA) pair, which is completed by the returned SAs from IKE. Connection manager then loads the connection to IPsec. An  
10   SA pair is two security associations (defined by RFC2401, supra), one inbound and one outbound.

          IPsec generates NAT rules for the two SAs. On outbound, NAT will occur after filtering and before IPsec and on inbound, NAT will occur after IPsec (and before  
15   filtering, if any). In this sense, NAT is 'wrapping' the local connection endpoint of the IPsec connection.

          Referring to Figures 3 and 4, conventional NAT functions are illustrated for background and contrast with later figures which show VPN NAT types according to the  
20   invention.

Referring to Figure 3, static is the simplest form of NAT. Both conventional NAT types are explicitly configured by the user by writing the corresponding NAT rule statements via the OpNav GUI. This is in contrast to the IPsec NAT, in which the actual NAT rules or statements are generated by the system. The MAP statement <MAP lhs TO rhs> of Figure 3 and the HIDE statement <HIDE ip addr set BEHIND rhs> of Figure 4 are such statements.

Again referring to Figure 3, on inbound processing, if source ip 70 matches lhs 72 in the MAP lhs TO rhs statement, then src ip 70 is translated to rhs 76. On outbound processing, if destination ip 74 matches rhs 76, then destination ip 74 is translated to lhs 72.

Referring to Figure 4, masquerade NAT (also referred to as network address and port translation (NAPT)), uses the HIDE statement, supra, and provides many-to-one address translation by using its own port pools 118 (UDP, TCP) to remember how to translate the inbound traffic. Unlike static NAT (Figure 3), masquerade NAT conversations <CONVERSATION src ip, src port, rhs ip, rhs port,...> can only be initiated by internal (lhs) addresses. VPN NAT, a name used to identify the preferred embodiment of the

present invention, as will be seen, is closer to static NAT,  
in that it does not include port translation.

Referring further to Figure 4, in processing outbound  
datagrams, in step <1> if source ip address 90 is determined  
5 to be in the ip address set 92 of the HIDE statement, then  
in step <2> the CONVERSATION is set up by copying src ip 90  
into CONVERSATION field 94, in step <3> source port 98 into  
field 96, in step <4> rhs 104 into field 100, and in step  
<5> the rhs port into field 102 from the correct pool in  
10 port pools 118. Then, in step <6> source ip 90 is  
translated to rhs 104, and in step <7> source port 98 is  
changed to rhs port 102. In processing inbound datagrams,  
if in step <8> destination ip address 106 and destination  
port 108 match CONVERSATION fields rhs ip 100 and rhs port  
15 102, respectively, then in step <9> destination ip address  
106 is translated to CONVERSATION source ip address 94 and  
in step <10> destination port 108 is translated to  
CONVERSATION source port 96.

Some special situations also handled by NAT are not  
20 illustrated because they are of no interest to the present  
invention. These include handling of special situations  
created by FTP or ICMP, both of which contain IP address

that are translated. FTP = File Transfer Protocol (defined  
in RFC959), and ICMP = Internet Control Message Protocol  
(defined in RFC792). Checksum re-calculation is done. In  
masquerade NAT once a conversation exists, later datagrams  
5 are matched against that, rather than the original  
(precipitating) HIDE rule, the port pools are managed,  
conversations are timed and terminated, and ports are  
mapped. It is a particular advantage of the invention that  
VPN NAT supports ICMP and FTP (including the famous FTP PORT  
10 and PASV commands and attendant problems).

In accordance with the present invention, dynamically  
determined VPN NAT rules are implemented as follows. The  
customer specifies, via a graphical user interface (GUI)  
that VPN NATing is to be done. Multiple IP addresses are  
15 allowed for the source IP address of locally initiated  
connections. These multiple IP addresses are specified via  
range (contiguous) or address and mask. These constitute  
the VPN NAT rule left-hand-side (lhs) address set. The VPN  
NAT rule right-hand-side (rhs) address set is associated  
20 with the remote VPN gateway address. When a connection is  
started, both lhs and rhs address sets are loaded with the  
connection as part of the IP Sec Security associations for  
the connection. The VPN Connection manager then marks the

rhs set as used to avoid NAT rule conflict, with connections started later.

As IP traffic occurs for a loaded (that is, installed into the operating system kernel), locally initiated, connection, the lhs and rhs address sets are used to determine what specific NAT rule should be applied to a particular datagram. The generation of a datagram-specific NAT rule is done by ordering each address set and each address in the lhs set is mapped, one-to-one, with the corresponding element of the rhs set. If the lhs set cardinality is larger than the rhs set, VPN NAT will not occur for the  $n$  elements of the lhs set where  $n > \text{cardinality}(\text{rhs})$ . (However, this may be prevented by audit at GUI level.) For outbound traffic, the  $n$ 'th element of the lhs set is selected based on the datagram source IP address, and for inbound traffic the  $n$ 'th element of the rhs set is selected based on (that is, equal to) the datagram destination IP address.

As IP traffic occurs for a loaded, remotely initiated connection (responder mode), the solution is essentially the same as for locally initiated connections, but reversed. In this case, the rhs set is matched against the inbound



09572416 093000  
002250 31222560

datagram destination IP address, which is mapped to the  
corresponding element of the lhs set. If the rhs set is  
greater than the lhs, NATing would simply not occur. Again,  
this may be undesirable from a human factor perspective, in  
5 which case it may be disallowed by audit at the GUI level.

Referring to Figures 5, 6 and 7, lhs and rhs refer to  
sets, such as contiguous ranges, of IP addresses. Assuming  
that x is a set, then size(x) designates the number of  
elements in the set. Three cases are provided, as follows:

10 Case 1:  $\text{size}(\text{lhs}) = \text{size}(\text{rhs}) = 1$ .

Case 2:  $\text{size}(\text{lhs}) = \text{size}(\text{rhs}) \ \& \ \text{size}(\text{lhs}) > 1$ .

Case 3:  $\text{size}(\text{lhs}) \neq \text{size}(\text{rhs})$ .

Case 1 is handled by the system and method of the  
parent application, U.S. Patent Application Serial No.  
15 09/240,720.

In case 2, since the two sets are equal, the implicit  
MAP rule generated for each connection as it is started is  
inherent in the statement of the two sets. That is, there

is a unique one-to-one correspondence between elements of the lhs and elements of the rhs. So, the generation of the implicit MAP rule for a particular VPN connection load is straightforward. For the process of Figure 5, for example,  
5 for source out VPN NAT, the n'th element of the lhs set that matches the source IP (step 1) is found, then the n'th element of the rhs set is found and used to replace the source IP (step 2).

In case 3, a dynamic association (a binding) of the lhs  
10 element with the rhs element is generated based on previously generated bindings. A binding is generated as needed, by traffic, or an existing binding is used. A binding lasts for the duration of the connection or until an inactivity time-out value is reached. The bindings are of  
15 two types: local and remote, and are unique across the system.

Which case is determined once, per VPN connection, at the time it is started, and not recomputed for each datagram handled.

20 Referring to Figure 5, the preferred embodiment of the invention for VPN NAT type a 'source-out' is illustrated.

In VPN NAT, type a 'source-out', IDci is translated for initiator-mode conversations. After system generated implicit NAT rule 128 <MAP lhs TO rhs> is loaded, it functions as static NAT. The key to making this work, is that the security associations negotiated by IKE use the implicit MAP 130 rhs 138. Hence, the SAs and the VPN NAT are synchronized.

Referring further to Figure 5, for a locally initiated conversation, in step <-2>, since NAT is requested, implicit MAP rule 128 is created by copying local client ID 122 to lhs 126, and the rhs 124 is obtained from the appropriate pool 120. Step <0> is part of starting a VPN connection, and occurs during steps 24 and 26 (Figure 1). In step <0>, after IKE negotiation is complete using rhs 124, implicit MAP rule 130 is loaded to the operating system kernel. This step <0> comprises the following steps; load the connection SA's, connection filter, and create blank version of table 210. For outbound processing, if in step <1> src ip 132 matches any particular lhs in implicit map rule 130, then in step <2> case 1, 2 or 3 (described above) is determined, resulting in a rhs 138 IP address. This selected rhs replaces source IP 132. An entry of the selected binding is made in the local binding table 210, if case 3. For inbound

processing, if in step <3> dest ip address 140 matches a rhs  
in the local binding table 210, then in step <4> destination  
ip 140 is replaced by the lhs of the local binding table  
entry 210.

5           lhs and rhs are two sets of IP addresses. A VPN NAT  
rule consists of one each, that is, it defines a mapping of  
lhs addresses on rhs addresses: lhs -> rhs.

10           In step 26 (Figure 1)+, responder mode connections are  
started. In so doing, IKE functions negotiate the SAs  
based on currently configured policy. When done, they are  
sent to the connection manager as a SA collection of 1 to n  
SA pairs.

          In Figures 6 and 7, VPN NAT source-in and  
destination-in types are illustrated.

15           Referring to Figure 8, the connection manager server  
300, upon receiving the start message (msg) 332 from IKE  
server 330, looks at the connection definition 306 in the  
database 304 and checks the NAT flags 314. If one or more  
NAT remote flags so 308, si 310, or di 312 is 'on', then an  
20   IP address(es) 154 (Figure 6), 186 (Figure 7) is obtained

from the appropriate NAT pool 50, 52 or 54 (Figure 2),  
depending on NAT flag associated with the ID 152 in (Figure  
6), 182 (Figure 7.)

The relationship between the NAT flag and NAT pools is;  
5 if source-out flag 308 is on or source-in flag 310 is on,  
pool type 52 (same type as 54) in Figure 2 is used,  
selecting the pool based on remote VPN connection endpoint  
address. If destination-in flag 312 is on, pool 50 in  
Figure 2 is used, indexed by destination address.

10 Management of IP address availability from the remote  
ID pool 150 is done by the connection manager based on its  
set of active connections (as for type a 'source-out' VPN  
NAT). Connection manager also handles availability for the  
15 IDcr pool 180 (Figure 7), which allows load balancing. The  
IDcr pool 180 is a set of IP addresses for nat'ing IDcr.  
There are two basic approaches: (1) for every start search  
the pool 180 from the first entry; or, (2) for every start,  
the pool 180 is searched from the last used IP.

The load to IPSec occurs as in the initiator mode case above. When processing remotely initiated connection traffic, two address translations may occur for each inbound and outbound packet (source and destination).

5 Referring to Figure 6, VPN NAT type c 'source-in' starts a responder-mode connection as follows: in step <-2>, implicit MAP rule 158 <MAP lhs TO rhs> is created, by copying IDci 152 to rhs 154; and in step <-1>, by selecting ip address(es) from the appropriate pool 150 and copied to  
10 lhs 156. In step <0>, after IKE negotiation is complete using rhs 154, implicit rule 160 is loaded. This step <0> includes the following: same as above -- step <0> is the same in all three VPN NAT types (except for some low-level details). When processing inbound datagrams, if in step <1>  
15 src ip 172 matches a rhs 168, in step <2>, source ip 172 is translated to corresponding lhs 166. Then, based on case 1,2 or 3 (as described above), an entry is made in the remote binding table 212. When processing outbound  
20 datagrams, if in step <3> destination IP 164 matches lhs 166, then in step <4> destination ip 164 is translated to rhs 168. The lookup for IP 164 used the remote binding table, if case 3, else it uses the implicit MAP rule 160.

Referring to Figure 7, VPN NAT d 'destination-in' type executes to translate IDcr for responder-mode conversations as follows: in step <-2> implicit MAP rule 188 is created, copying IDcr 182 to rhs 184. In step <-1>, ip address(es) are obtained from appropriate address pool 180 and copied to lhs 186. In step <0>, after IKE negotiations are completed using rhs 184, implicit MAP rule 190 is loaded. (Step <0> is the same as for Figures 5 and 6, except for low-level details.)

When processing inbound datagrams if in step <1> destination ip 200 matches rhs 198, in step <2> destination ip 200 is translated to lhs 196. When processing outbound datagrams if in step <3> source ip 192 matches lhs 196, in step <4> source ip 192 is translated to rhs 198.

Referring to Figure 8, in step 28, when the connection manager 300 gets SA pair updates 302, it copies the new SA pair information to the SA pair table 322 in connection process memory 320.

In step 30, when ending a connection 34, 36, the connection manager 300 frees (makes available) any NAT IP addresses 52, 54 associated with the connection. Referring

to Figure 8, NAT IP addresses are removed from the appropriate list 316 maintained by the connection manager 300.

5       The size of the lhs and rhs sets is controlled by taking the minimum of three items: the subnet size (or address range) configured by the customer, the maximum concurrent VPN NAT sessions per connection configured by the customer on a per NAT pool basis, and the size of the largest remaining range of value still available in the  
10       originally configured pool. This is determined by the VPN connection manager during the startup of a connection (step 24 and 26, Figure 1).

#### **Advantages over the Prior Art**

15       It is an advantage of the invention that there is provided an improved and greatly simplified system and method for concurrently implementing both Network Address Translation (NAT) and IP Security (IP Sec).



It is a further advantage of the invention that there is provided a system and method for solving the increased likelihood of IP address conflicts inherent in the use of a virtual private network (VPN).

5           It is a further advantage of the invention that there is provided a system and method for enabling utilization of VPNs without requiring re-addressing a domain (an expensive alternative).

10           It is a further advantage of the invention that there is provided a system and method for VPN NAT which is accomplished entirely in the IP Sec gateway without requiring changes in domain hosts.

15           It is a further advantage of the invention that there is provided a system and method for VPN NAT which requires no, or only minor, changes to routing in each connected domain.

          It is a further advantage of the invention that there is provided a system and method for VPN NAT which is simple to configure.





Further, each step of the method may be executed on any general computer, such as an IBM System 390, AS/400, PC or the like and pursuant to one or more, or a part of one or more, program elements, modules or objects generated from any programming language, such as C++, Java, Pl/1, Fortran or the like. And still further, each said step, or a file or object or the like implementing each said step, may be executed by special purpose hardware or a circuit module designed for that purpose.

10

Accordingly, the scope of protection of this invention is limited only by the following claims and their equivalents.

## CLAIMS

We claim:

- 1        1.    A method of operating a virtual private network (VPN)  
2            based on IP Sec that integrates network address  
3            translation (NAT) with IP Sec processing, comprising  
4            the steps of:  
  
5            configuring a NAT IP address pool;  
  
6            configuring a VPN connection to utilize said NAT IP  
7            address pool;  
  
8            obtaining a specific IP address from said NAT IP  
9            address pool, and allocating said specific IP address  
10          for said VPN connection;  
  
11          starting said VPN connection;  
  
12          loading to an operating system kernel the security  
13          associations and connection filters for said VPN  
14          connection;

15           processing a IP datagram for said VPN connection; and

16           applying VPN NAT to said IP datagram.

1        2.     The method of claim 1, wherein said VPN connection is  
2                configured for outbound processing, and said applying  
3                step comprises outbound source IP Nating.

1        3.    The method of claim 1, wherein said VPN connection is  
2            configured for some combination of inbound processing,  
3            and said applying step selectively comprises inbound  
4            source IP NATing or inbound destination IP NATing.

1        4.    The method of claim 1, further for integration of NAT  
2            with IP Sec for manually-keyed IP Sec connections,  
3            comprising the further step of manually configuring  
4            connection keys.

1        5.    The method of claim 1, further for integrating NAT with  
2            IP sec for dynamically-keyed (e.g. IKE) IP Sec  
3            connections, comprising the further step of:

```
4      configuring the VPN connections to obtain their keys
5      automatically.
```

1        6.    The method of claim 1, further for integrating NAT with  
2            IP Sec Security Associations, negotiated dynamically by  
3            IKE, wherein said starting step further comprises  
4            creating a message for IKE containing said IP address  
5            from said NAT pool; and further comprising the step of  
6            operating IKE to obtain dynamically negotiated keys.

1        7.    The method of claim 6, further comprising the step of  
2            combining the dynamically obtained keys with said NAT  
3            pool IP address and wherein said loading step loads the  
4            result as security associations into said operating  
5            system kernel.

1       8.    A method for allowing the definition and configuration  
2            of NAT directly with definition and configuration of  
3            IPsec-based VPN connections and VPN policy, comprising  
4            the steps of:

5 configuring the requirement for VPN NAT by a yes/no  
6 decision in a policy database for each of the three  
7 types of VPN NAT, said three types being VPN NAT type a















5 integrates network address translation (NAT) with IP

6 Sec processing, said method steps comprising:

```
7      configuring a NAT IP address pool;
```

8           configuring a VPN connection to utilize said NAT IP  
9           address pool;

```

10         obtaining a specific IP address from said NAT IP
11         address pool, and allocating said specific IP address
12         for said VPN connection;

```

```
13         starting said VPN connection;
```

14 loading to an operating system kernel the security  
15 associations and connection filters for said VPN  
16 connection;

17           processing a IP datagram for said VPN connection; and

18       applying VPN NAT to said IP datagram.

1      20. An article of manufacture comprising:

2 a computer useable medium having computer readable  
3 program code means embodied therein for operating a  
4 virtual private network (VPN) based on IP Sec that  
5 integrates network address translation (NAT) with IP  
6 Sec processing , the computer readable program means in  
7 said article of manufacture comprising:

8 computer readable program code means for causing a  
9 computer to effect configuring a NAT IP address pool;

10 computer readable program code means for causing a  
11 computer to effect configuring a VPN connection to  
12 utilize said NAT IP address pool;

13 computer readable program code means for causing a  
14 computer to effect obtaining a specific IP address from  
15 said NAT IP address pool, and allocating said specific  
16 IP address for said VPN connection;

17 computer readable program code means for causing a  
18 computer to effect starting said VPN connection;

19 computer readable program code means for causing a  
20 computer to effect loading to an operating system  
21 kernel the security associations and connection filters  
22 for said VPN connection;

23 computer readable program code means for causing a  
24 computer to effect processing a IP datagram for said  
25 VPN connection; and

26 computer readable program code means for causing a  
27 computer to effect applying VPN NAT to said IP  
28 datagram.

21. Method for providing IP security in a virtual private network using network address translation (NAT), comprising the steps of:

4       dynamically generating NAT rules and associating them  
5       with manual or dynamically generated (IKE) Security  
6       Associations; thereafter

7       beginning IP security that uses the Security  
8       Associations; and then

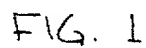




**SYSTEM AND METHOD FOR NETWORK ADDRESS TRANSLATION  
INTEGRATION WITH IP SECURITY**

**Abstract of the Disclosure**

IP security is provided in a virtual private network  
5 using network address translation (NAT) by performing one or  
a combination of the four types of VPN NAT, including VPN  
NAT type 'a source-outbound' IP NAT, VPN NAT type 'b  
destination-outbound, VPN NAT type 'c inbound-source' IP  
NAT, and VPN NAT type 'd inbound-destination' IP NAT. This  
10 involves dynamically generating NAT rules and associating  
them with the manual or dynamically generated (IKE) Security  
Associations, before beginning IP security that uses the  
Security Associations. Then, as IP Sec is performed on  
outbound and inbound datagrams, the NAT function is also  
15 performed.



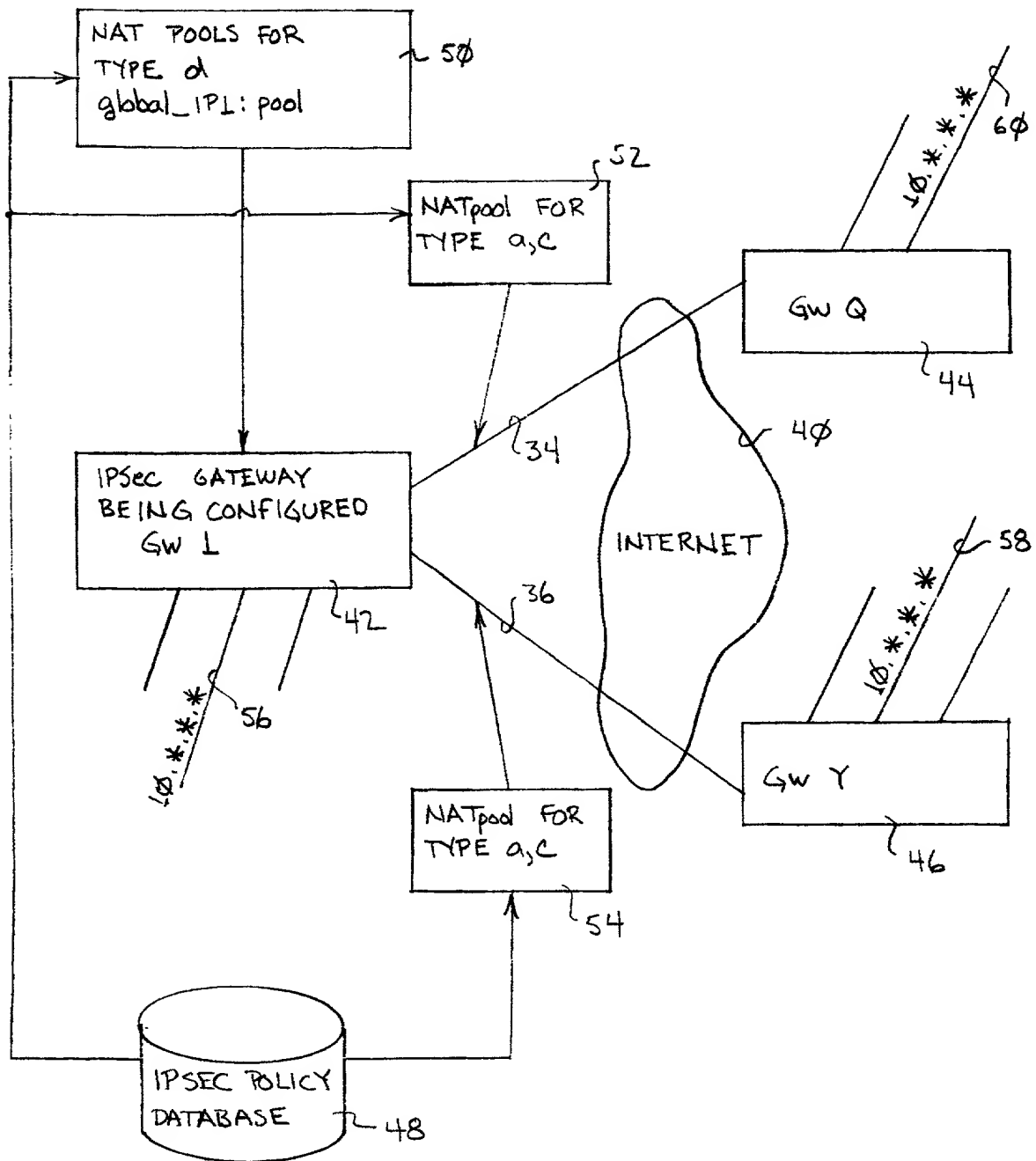


FIG. 2

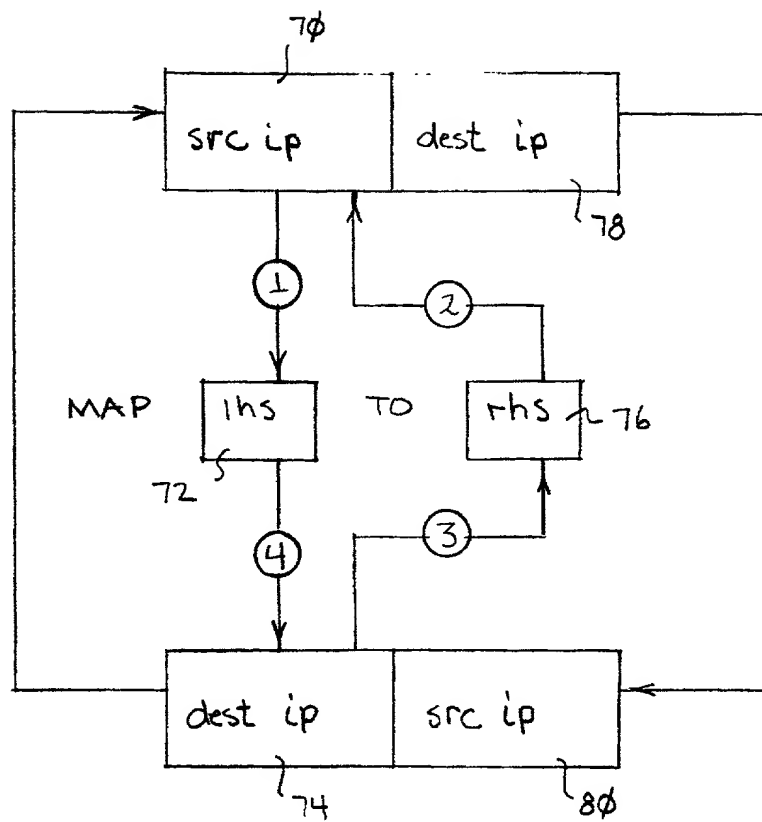


FIG. 3.

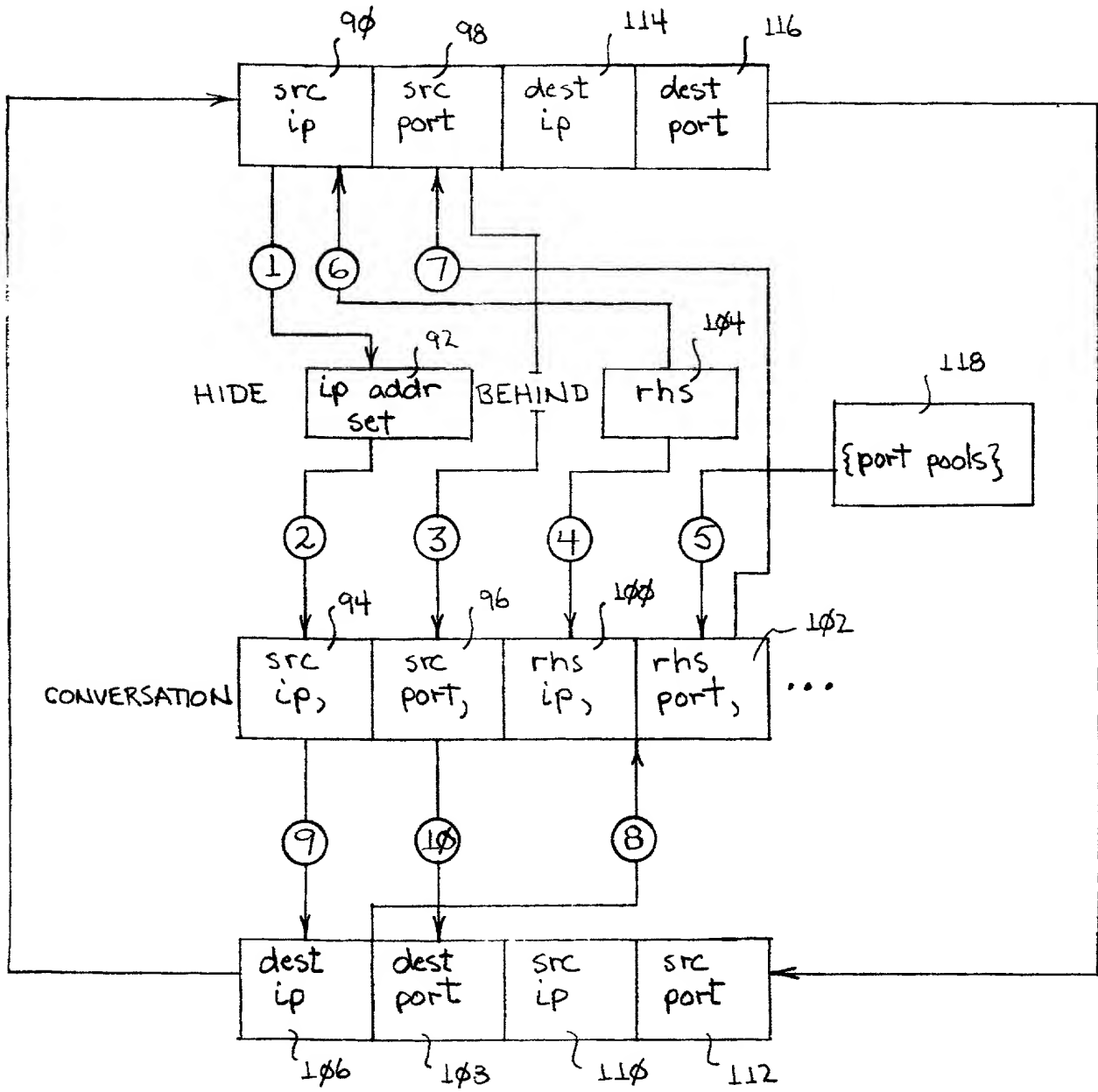
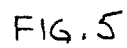


FIG. 4



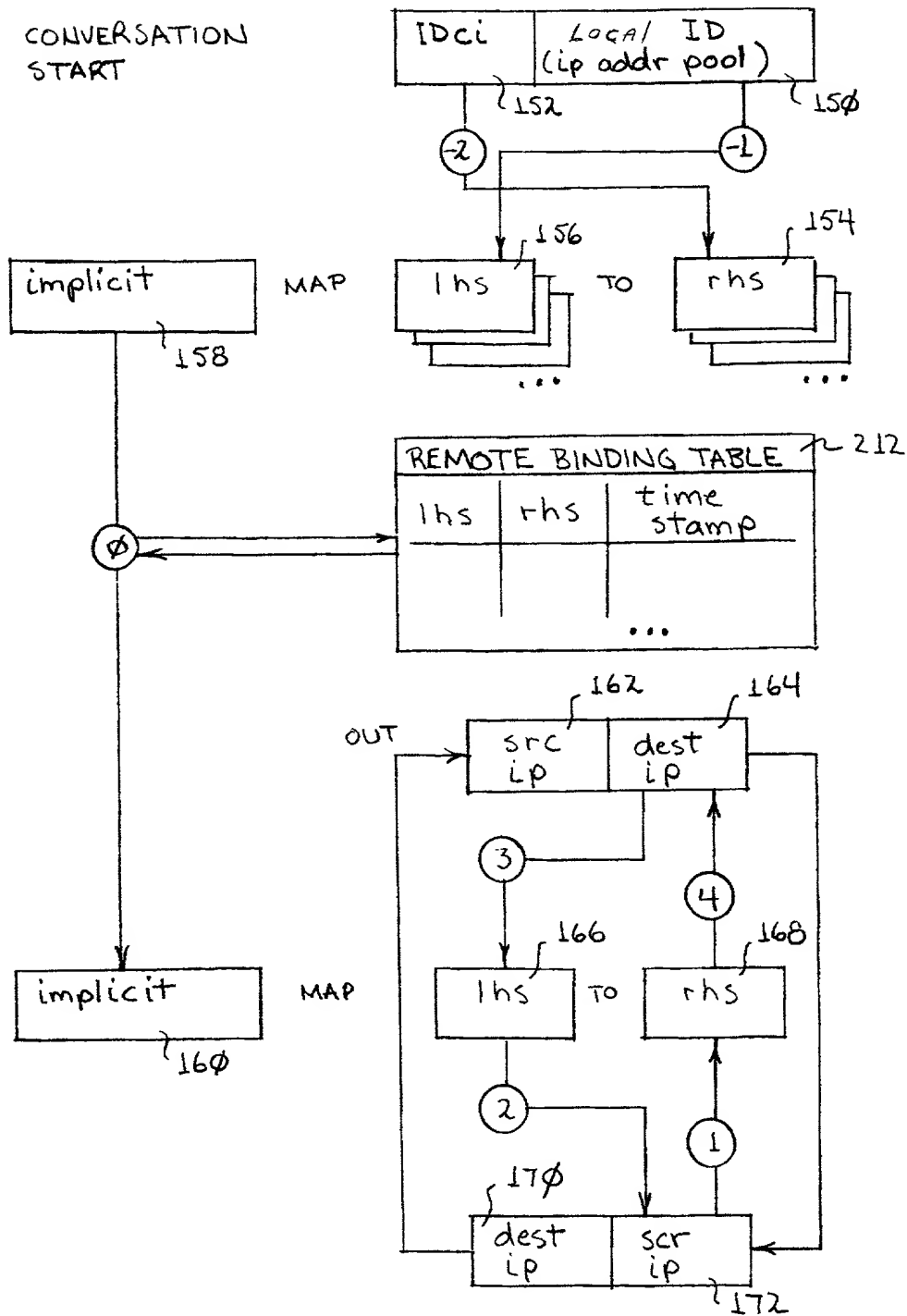
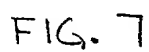


FIG. 6

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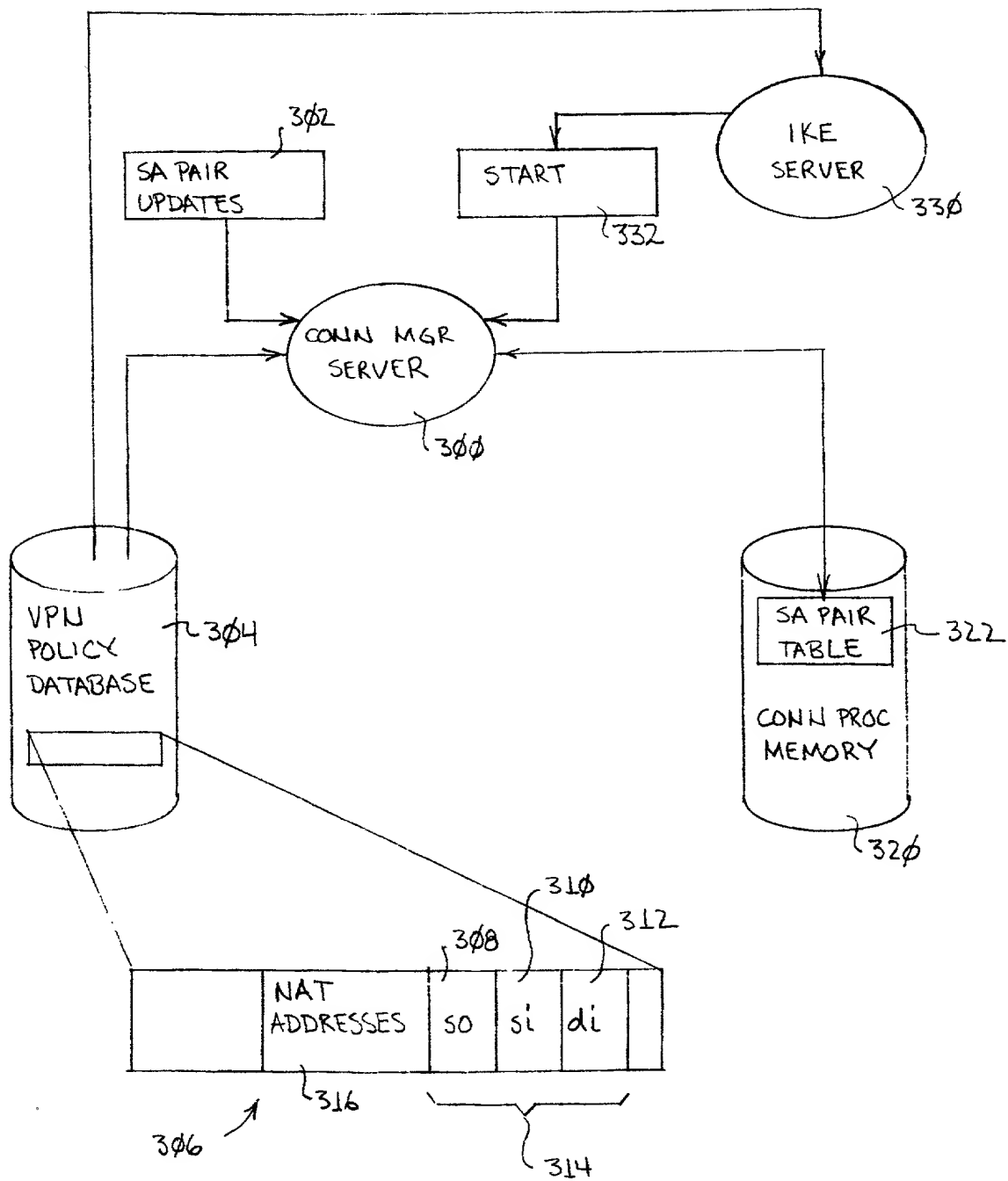


FIG. 8

**DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **SYSTEM AND METHOD FOR NETWORK ADDRESS TRANSLATION INTEGRATION WITH IP SECURITY**

the specification of which (check one)

  X   is attached hereto.

                     was filed on                      as Application Serial No. or PCAT International Application No.                      and was amended on                      (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventors certificate, or PCAT International application having a filing date before that of the application on which priority is claimed::

Prior Foreign Application(s):

Number	Country	Date/Month/Year	Priority Claimed
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I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below.

Application Number	Filing Date
--------------------	-------------

I hereby claim the benefit under Title 35, United States Code, section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose information material to patentability of this application as defined in 37 CFR Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

Prior U.S. Applications:

Serial No.	Filing Date	Status (patented, pending, abandoned)
09/240,720	1/29/99	Pending

09240720.03292500

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